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ORIGINAL PAPER

Characteristics of soil seed bank in plantation forest in the rocky mountain region of Beijing, China

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Abstract: We investigated characteristics (scales and composition) of soil seed banks at eight study sites in the rocky mountain region of Beijing by seed identification and germination monitoring. We also surveyed the vegetation communities at the eight study sites to explore the role of soil seed banks in vegetation restoration. The storage capacity of soil seed banks at the eight sites ranked from 766.26 to 2461.92 seeds·m^{-2}. A total of 23 plant species were found in soil seed banks, of which 63−80% of seeds were herbs in various soil layers and 60% of seeds were located in the soil layer at 0−5 cm depth. Biodiversity indices indicated clear differences in species diversity of soil seed banks among different plant communities. The species composition of aboveground vegetation showed low similarity with that based on soil seed banks. In the above-ground plant community, the afforestation tree species showed high importance values. The plant species originating from soil seed banks represented natural regeneration, which also showed relatively high importance values. This study suggests that in the rocky mountain region of Beijing the soil seed banks played a key role in the transformation from pure plantation forest to near-natural forest, promoting natural ecological processes, and the role of the seed banks in vegetation restoration was important to the improvement of ecological restoration methods.

Keywords: Rocky mountain region of Beijing; soil seed bank; plant community; plant diversity; vegetation regeneration

Introduction

A soil seed bank is the sum of all surviving seeds in the litter and soil (Zhao et al. 2003). Similar to the above-ground parts of plants, a soil seed bank constitutes a potential plant community that is an important part of an ecosystem (Coffin and Lauenroth 1989). A soil seed bank is understood to be an integral component of plant communities (James et al. 2007) and can be used to predict secondary succession (Pakeman and Hay 1996). Previous studies on soil seed banks mainly focused on the topics of spatial distribution of seeds, seed density, species richness, composition of the soil seed bank, and the relation between the soil seed bank and the above-ground plants in heathlands, grasslands, and forests, especially in Europe and North America (Hopfensperger 2007). The regenerative role of the soil seed bank is another research field and attracts increasing attention. Soil seed banks are successfully used in the restoration of wetland vegetation in Canada (Madsen 1986) and restoration of vegetation on mine spoils in Australia (Li et al. 1980; Tacey and Glossop 1980). Li et al. (2010) described the role of soil seeds and seedling banks in the regeneration of diverse plant communities in the subtropical Ailao Mountains of China.

There is a large rocky mountain region in the northwest of the administrative area of Beijing. One thousand years ago, this region was covered by thick forest but in the beginning of the 20th century, the forest was largely destroyed by human activities including deforestation, logging and fire, and forest coverage dropped below 2%. Forest coverage was increased to 40.9% through large-scale afforestation after 1949. However, in the low-mountain zone, owing to the harsh site conditions of the rocky mountain region, including poor soil, drought, low winter temperatures, and strong winds, the planted trees grew slowly,

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resulting in slow progress of vegetation restoration: the prevailing vegetation type is indigenous shrub. Most previous studies of ecological restoration in this region focused on measuring the ecological indices on mine spoils, and little attention was paid to the characteristics of the soil seed bank and its role in ecological restoration. Thus the regenerative potential of the seed bank in this region is little known.

We investigated vegetation restoration of different plant communities and the basic characteristics and rules of the soil seed bank in regeneration of plant communities in the rocky mountain region of the low-mountain zone of Beijing. Our objective was to explore the potential effectiveness of soil seed bank in vegetation restoration and biodiversity conservation. We aimed to provide theoretical support for restoration and reconstruction of vegetation in the rocky mountain region.

Materials and methods

Site description

The study area, Beijing West Mountain Experimental Tree Farm, is located at Xiao Xi Shan Mountain in the western suburb of Beijing (N40º2′8″, E116º15'48″). This region is characterized by a typical sub-humid warm temperate continental monsoon climate. Annual mean air temperature is 14°C, annual mean precipitation 567.9 mm, and annual mean sunshine is about 2600 h. The parent rock is greywacke. The site condition of this region is poor and soils lack nutrients. From the 1950s, afforestation was carried out on the barren mountains in this tree farm using tree species with high drought-resistance and tolerance of poor soils, including *Platycladus orientalis*, *Pinus tabulaeformis*, *Robinia pseudoacacia*, *Cotinus coggygria*, *Acer truncatum*, *Koelreuteria paniculata*, *Quercus variabilis*, *Prunus davidiana*, *Prunus armeniaca*.

Our eight study sites covered 400 m^2 each at elevations of 130 to 170 m and were selected according to forestation tree species. We categorized the eight sites into four different vegetation types including deciduous broadleaf forest, shrubbery, coniferous forest, and coniferous and deciduous broadleaf mixed forest (Table 1).

Analysis of soil seed bank

The line transect method was used to investigate soil seed banks in late March 2009 prior to natural germination of seeds. A long line was set across a study site, and five sampling plots of 1 m^2 area (1m × 1 m) were set along with this line (with the minimum distance of 5 m between plots). Ten sampling points were set randomly in every plot. One soil core (10 cm×10 cm × 10 cm) was taken from every sampling point. These soil samples were put in numbered self-sealing bags and later used for seed identification and germination tests.

Table 1. Basic characteristics of eight study sites in Xiao Xi Shan Mountain, western suburb of Beijing

No.	Vegetation type	Tree species for afforestation	Naturally regenerating tree species	Crown density (%)	Litter thickness (cm)	Humus thickness (cm)	Solum thickness (cm)
2	shrubbery	*Ziziphus spinosus*	*Broussonetia papyrifera*, *Ziziphus jujube*, *Vitex negundo* var. *heterophylla*	70	1.0	1.2	7.5
1	deciduous broadleaf forest	*Broussonetia papyrifera*	*Ziziphus jujube*, *Robinia pseudoacacia*, *Leapedeza bicolor*, *Vitex negundo* var. *heterophylla*	95	1.5	3.2	10.5
3	deciduous broadleaf forest	*Robinia pseudoacacia*	*Broussonetia papyrifera*, *Cotinus coggygria*, *Leapedeza bicolor*	90	3.5	2.8	18.0
5	deciduous broadleaf forest	*Prunus davidiana*	*Prunus davidiana, Vitex negundo* var. *heterophylla*, *Broussonetia papyrifera*, *Ziziphus jujube*	85	2.3	2.2	13.0
8	deciduous broadleaf forest	*Cotinus coggygria*	*Broussonetia papyrifera*, *Cotinus coggygria*, *Leapedeza bicolor*, *Vitex negundo var. heterophylla*, *Grewia biloba* G. Don var. *parviflora* (Bunge) Hand.-Mazz.	95	2.6	3.5	17.5
4	coniferous and deciduous broadleaf mixed forest	*Acer mono*	*Acer mono Maxim*, *Vitex negundo var. heterophylla*, *Grewia biloba* G. Don var. *parviflora* (Bunge) Hand.-Mazz.	75	2.2	1.9	13.5
6	coniferous and deciduous broadleaf mixed forest	*Quercus variabilis*	*Cotinus coggygria*, *Leapedeza bicolor*	83	1.0	1.4	8.5
7	coniferous forest	*Platycladus orientalis*	*Ziziphus jujube*, *Leapedeza bicolor*, *Vitex negundo* var. *heterophylla*	95	3.2	3.5	18.5

Note: Naturally regenerating trees were considered to be those with basal diameter <2 cm.

Seed identification

The collected soil samples were screened through a 50-mesh sieve to separate seeds from soil. The physical method was used to identify the species of seeds. Seed vigor was tested using the tetrazolium staining method (Fu 1985), and the vigorous seeds were numbered.

Germination test

Germination tests were carried out in a green house. The screened soil was spread out on seedbeds of 2 cm thickness (Li

and Liu 2002). An amount of water was sprayed on the soil every day as needed to keep the soil moist. Seedling emergence was checked and recorded every three days. Individuals that were difficult to identify were transplanted to larger containers to allow for growth and later identification. When no seedlings emerged, the soil was allowed to dry, loosened softly, and re-wetted. Emerging seedlings were again identified. At the end, GA_3 solution of 1 $g \cdot L^{-1}$ was sprayed in order to remove seed dormancy (Yu and Jiang 2003). When no seedlings of new species emerged after four weeks in succession, the test was stopped.

Investigation of community property

The community properties of eight study sites were investigated in August 2009. For herbs, at each study site eight sampling plots (l m × 1 m) were chosen randomly, and at least 3 m intervals were maintained. Then the species of herbs and their abundance, coverage, frequency were recorded in each plot. For woody plants, five plots (5 m × 5 m) were chosen randomly at each study site with the minimum interval of 20 m. We recorded species of trees and shrubs, and calculated their abundance, coverage, and frequency. We also recorded crown diameter and breast-height diameter. The species and quantity of woody plants that grew due to natural regeneration were also examined.

Data analysis

All statistical analyses were conducted using Excel and SPSS (version 13.0) statistical software. Indices of soil seed banks were calculated using the follows equations:

Species richness of seed banks was estimated using Margalef's richness index (Sun et al. 1993):

$$R = \frac{S-1}{LnN} \quad (1)$$

Diversity of seed banks was estimated using Shannon-Wiener's diversity index (Sun et al. 1993):

$$H = -\sum_{i=1}^{s}(P_i LnP_i) \quad (2)$$

And Simpson's diversity index:

$$D = 1 - \sum_{i=1}^{s}\frac{N_i(N_i-1)}{N(N-1)} \quad (3)$$

The homogenization parameter of seed banks was estimated using Pielou's equation (Ren 1998):

$$E = \frac{H}{LnS} \quad (4)$$

Similarity coefficients of seed banks were estimated using Sørensen similarity index:

$$CC = \frac{2C}{S_1 + S_2} \quad (5)$$

In these equations, S indicates the total number of species in the soil seed bank, N the total number of seeds in the soil seed bank, P_i is the percentage represented by the i-th species of the total number of seeds in the soil seed bank (N_i/N), C is the number of species that were found both in the plant community and in the soil seed bank; $S1$ and $S2$ indicate the number of species in plant community and soil seed bank, respectively. The importance value was used as a comprehensive index to quantify the plant community.

The important value of trees: $\frac{1}{3}$ × (relative abundance + relative frequency + relative prominence)

The important values of shrubs and herbs: $\frac{1}{3}$ × (relative abundance + relative frequency + relative coverage)

Results

Densities and vertical distribution of soil seed banks

Seed densities of the eight soil seed banks varied significantly between the eight study sites (F=5.308, $p < 0.05$) (Fig. 1). Maximum seed density was at site 8 (2461.92 seed·m^{-2}), which contained 3.2 times more seed than at site 1.

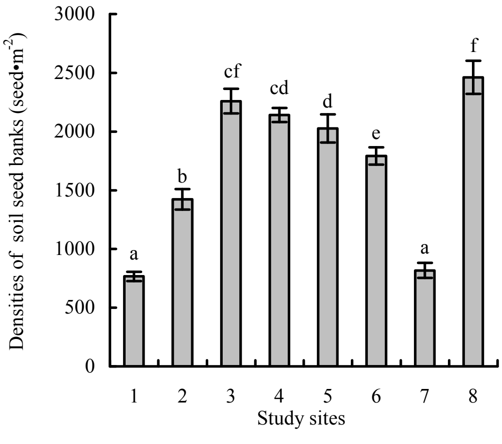

Fig. 1 Seed densities of soil seed banks at 8 study sites

In this study, soil layers were divided into three parts (0–3 cm, 4–6 cm, and 7–10 cm). Seed density of soil seed banks was vertically distributed in these three soil layers (Table 2). Seed densities declined gradually at increasing soil depths. The highest proportion (39.08%–68.33%) of seeds was found in the 0–3 cm soil layer, and the smallest proportion in the 7–10 cm soil layer (0–2.29%). Seed density in litter layers also varied. At sites 1, 6, and 7, the proportions of seeds in the litter layer were clearly lower than at other sites.

Table 2. Vertical distribution of soil seed banks in eight study sites

Site No.	Total seed density (seed·m^{-2})	Litter layer		Soil layer 0-10 cm		Soil layer 0-3 cm		Soil layer 4-6 cm		Soil layer 7-10 cm	
		Density (seed·m^{-2})	Proportion (%)	Density (seed·m^{-2})	Proportion (%)	Density (seed·m^{-2})	Proportion (%)	Density (seed·m^{-2})	Proportion (%)	Density (seed·m^{-2})	Proportion (%)
1	766.26±39.70	37.81±7.11	4.93	728.45±32.59	95.07	489.09±17.38	63.83	239.36±15.21	31.24	0	0
2	1422.38±87.81	157.94±14.89	11.1	1264.44±72.92	88.9	764.87±37.77	53.77	473.61±30.94	33.3	25.97±4.21	1.83
3	2258.09±104.78	366.83±28.36	16.25	1891.25±76.42	83.75	1058.31±26.06	46.87	781.14±39.47	34.59	51.81±10.89	2.29
4	2140.79±60.03	579.08±21.89	27.05	1561.71±38.14	72.95	1180.89±19.67	55.16	355.75±12.14	16.62	25.08±6.33	1.17
5	2026.71±120.27	673±47.32	33.21	1353.72±72.95	66.79	791.97±39.28	39.08	522.09±25.98	25.76	39.66±7.69	1.96
6	1792.18±73.01	135.92±10.97	7.58	1656.26±62.04	92.42	1224.67±49.21	68.33	431.59±12.83	24.08	0	0
7	817.11±64.79	49.64±13.09	6.08	767.47±51.70	93.92	475.39±41.05	58.18	292.08±10.65	35.75	0	0
8	2461.92±141.02	647.33±24.58	26.29	1814.59±116.44	73.71	1308.86±80.53	53.16	458.35±23.78	18.62	47.39±12.13	1.92

Composition and life style of soil seed banks

In germination tests, 39 plant species were identified in soil seed banks from eight study sites, representing 24 plant families. Twenty-three species of 16 families were recorded in the soil seed bank at site 3, while only 9 species of 7 families were found in the soil seed bank at site 1.

At the eight study sites, a high proportion of herbs were found in soil seed banks (Fig. 2). The highest proportion of herbs (80%) was recorded at site 2 and the lowest proportion (60%) was found in site 1. Seeds of woody plants were recorded at low proportions in comparison with other plant types. Site 1 had the highest proportion of woody plant seeds (36%). Compared to site 1 (dominated by shrubs) and site 8 (dominated by coniferous forest), higher proportions of woody plant seeds were found at sites 2, 3, 4, 5 (deciduous broadleaf forest) and sites 6, 7 (coniferous and deciduous broadleaf mixed forest).

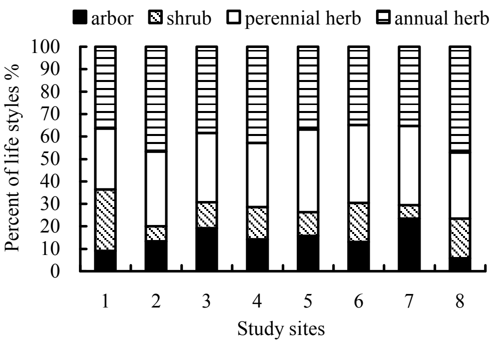

Fig. 2 Life styles of plants in soil seed banks

Among the species recorded in soil seed banks, woody species included *Robinia pseudoacacia*, *Broussonetia papyrifera*, *Quercus variabilis*, *Quercus acutissima*, *Picea asperata*, *Acer mono* Maxim., *Prunus davidiana*, *Platycladus orientalis*, *Cotinus coggygria*, *Ziziphus jujube*, *Periploca sepium*, *Leapedeza bicolor*, *Vitex negundo* var. *heterophylla*, *Spiraea trilobata*, *Caragana sinica*, *et al*. Most of these species were typical of early successional stages or dominant species of the community. Among these plants, *R. pseudoacacia*, *Q. variabilis*, *P. davidiana*, *A. mono* Maxim., *P. orientalis*, and *C. coggygria* were planted; and the other species, including *B. papyrifera*, *Q. acutissima*, *P. asperata*, *Z. jujube*, *P. sepium*, *L. bicolor*, *V. negundo* var. *heterophylla*, *S. trilobata*, and *C. sinica* regenerated naturally.

At the eight study sites, herbs of Gramineae, Compositae, Verbenaceae, Portulacaceae, Amaranthaceae, and Scrophulariaceae were recorded. Herbs of Chenopodiaceae, Rubiaceae, Brassicaceae, Labiatae, Leguminosae, Violaceae, and Boraginaceae were also frequently recorded. Herb species of Gramineae and Compositae were more abundant than were plants of other families. Among all herbs, *S. Viridis*, *A. retroflexus* L., *B. pilosa* L., and *R. glutinosa* showed highest frequency of occurrence.

Richness and diversity of soil seed banks

The soil seed banks at the eight study sites presented different patterns of richness, diversity, and homogenization (Fig. 3). Sites 3 and 6 showed highest species richness and diversity. The other six sites did not differ significantly in these two indices.

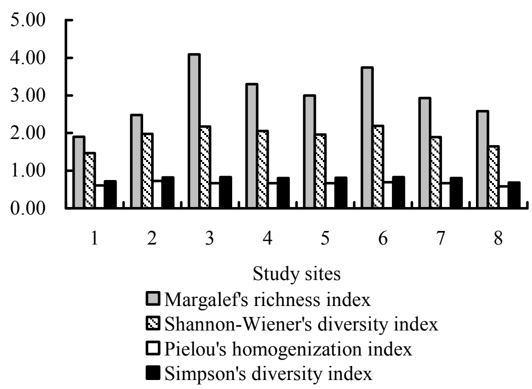

Fig. 3 Species diversity of soil seed banks

Similarities between soil seed banks and aboveground vegetation

Importance values of plant communities at the eight study sites are listed in Table 3. In the arbor layer, site 3 had highest species richness (8 species), while only one tree species (*B. papyifera*) was recorded at site 1. Three afforestation tree species showed

high importance value. The importance value of *P. orientalis* at site 8 reached 90.52%. The importance values of *A. elegantulum* at site 6 and *C. coggygria* at site 5 were 79.67% and 73.57%, respectively. In the shrub layer, four species, *Z. jujube*, *V. negundo*, *L. bicolor*, and *G. biloba*, occurred at high frequencies at all study sites. *V. negundo* in particular occurred with relatively high importance in all plots with the highest values (55.86%) at site 2. All of the shrub plants were rooted in the soil seed bank and all are characterized by high adaptability, so they grew well on the rocky mountains. In the herb layer, site 3 had 13 species whose importance values exceeded 5%, and species richness was greater than at other sites. At site 3, herbs occurred with similar importance values, excepting *A. lanceolatus* with a relatively high importance value of 18.79%: this reflected the high shrub species richness. At other sites, one herb species occurred at an importance value exceeding 30% (*S. viridis* at site 1), while *A. lanceolatus* in the other plots had the highest importance value, indicating its important role in the plant community..

Table 3. Importance value of dominant species at the eight study sites

Layer	Plant species	Importance value (%)							
		site 1	site 2	site 3	site 4	site 5	site 6	site 7	site 8
	Ailanthus altissima					3.11			
	Amygdalus davidiana				51.9				
	Acer elegantulum			6.45			79.67		
	Broussonetia papyifera	100	60.01	24.23	45.12	12.71	4.5	2.71	
	Celtis bungeana			4.08		6.3	3.5		
	Cotinus coggygria		3.69	4.75		73.57		9.19	6.13
	Castanea mollissima		6.89						
	Fraxinus chinensis			4.4					
Arbor	*Gleditsia sinensis*			11.61					
	Koelreuteria paniculata			4.45	2.98		4.79	2.45	
	Morus alba						3.3		3.35
	Platycladus orientalis					2.66	4.24	13.56	90.52
	Quercus aliena							3.64	
	Quercus variabilis							68.45	
	Robinia pseudoacacia		29.41	40.03					
	Ulmus pumila					1.65			
	Total	100	100	100	100	100	100	100	100
	Caragana sinica						13.77		
	Grewia biloba			25.6	6.51	33.33	31.94	22.86	9.27
	Lespedeza bicolor		19.56	50.65	3.12	29.17		58.1	16.45
	Leptopus chinensis						16.13		
Shrub	*Rhamnus parvifolia*		3.49		2.81				
	Spiraea trilobata			11.77	4.6				
	Vitex negundo	39.08	55.86	11.98	44.26	37.5	38.16	19.04	56.9
	Ziziphus spinosus	60.92	21.09		38.7				17.38
	Total	100	100	100	100	100	100	100	100
	Artemisia annua			7.36					
	Arthraxon lanceolatus	37.95		18.79	42.2	45.11	33.18	31.8	51.69
	Amaranthus retroflexus		13.35	5.96	13.8	8.78		8.17	
	Bidens pilosa			7.66				8.29	
	Chenopodium album	13.37	18.08	7.3			11.37		
	Cleistogenes hancei	8.85	15.36	5.07	13.46	9.67		10.64	14.78
	Carex tristachya			7.07			9.75	10.9	12.09
	Dendranthema indicum	10.43							15.44
Herb	*Ixeris polycephala*	7.44		5.49		7.89	12.8	9.31	
	Orychophragmus violaceus			6.18			12.8		
	Rubia cordifolia	8.02	14.06	5.18	13.13	7.89			
	Rehmannia glutinosa			5.48				8.87	
	Setaria viridis		34.15			13.67		8.87	
	Trigonotis amblyosepala			6.3			9.09		
	Viola philippica	9.94		7.66	12.4		7.95		
	Total	96	95	95.5	94.99	93.01	96.94	96.85	94

Note: The plants whose importance values are less than 5% are not present in the table.

Fig. 4 shows similarity coefficients between soil seed banks and aboveground vegetation at the eight sites. Site 3 showed the highest similarity coefficient (0.391) and site 8 the lowest (0.138). Several herb species (*A. lanceolatus*, *C. hancei*, *R. glutinosa*, and *S. viridis*) were found both in the soil seed bank and the aboveground vegetation. In addition, woody plants including *R. pseudoacacia*, *Q. variabilis*, *P. orientalis*, *C. coggygria*, *A. elegantulum*, *A. davidiana*, *Z. jujube* were also found both in the soil seed bank and aboveground

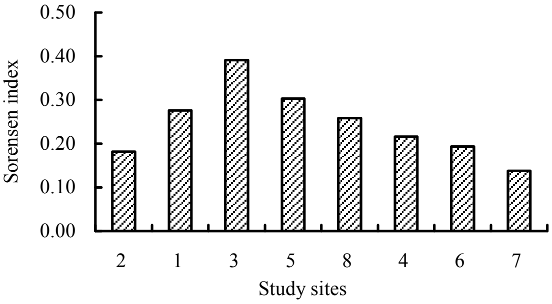

Fig. 4 Similarity coefficient between soil seed banks and aboveground vegetation

Discussion

Characteristics of soil seed bank

We found significant differences in the densities of seed in the soil seed bank between study sites, which also had different afforestation tree species. An et al. (1996) investigated the soil seed bank of Baohua Mountain and found that seed density ranged from 145 to 225 seeds·m^{-2}. Previous studies reported that the density of seeds in forest soils ranged from 102 to 103 seed·m^{-2}, in grassland soils from 103 to l06 seeds·m^{-2} and in cultivated soil from 103 to l05 seeds·m^{-2} (Harper 1977; Sitvertown 1982). In this study, the density of seed banks at all eight study sites was relatively high. The lowest seed density exceeded 700 seed·m^{-2} (site 1), and the highest density nearly reached 2300 seed·m^{-2}. Huang et al. (1996) showed that seed density declined gradually with plant community development and succession, being greatest during early succession. In this study, the plant communities at all study sites were in early successional stages, and herbs were the main plant species, leading to relative high seed density. Among the 39 plant species recorded in the soil seed banks, herbs accounted for 63.64%–80.00%, and most were annual plants, also suggesting that the plant community was at an early successional stage.

Soil seed density declined with soil depth. Seed density was highest in the 0–3 cm soil layer while the deepest sampled layer, 7–10 cm, accounted for just 2% of the total seed count in the soil. Liu et al. (2008) reported that on Baihua Mountain seeds in the litter layer accounted for 30.8%–77.3% of the total number of seeds. In this study, however, the litter layers held only 4.93%–33.21% of total seeds. Less abundant seeds in the litter layer at our study sites might be attributable to the typically thin litter layer.

Based on Margalef's richness index and the Shannon-Wiener diversity index, site 1 had the lowest seed species diversity in the soil seed bank. The plant community at site 1 was dominated by *Z. spinosus* and *V. negundo* var. *heterophylla*. The shrub dominated plant community did not provide canopy coverage needed by shade-requiring plants, accounting for their paucity at site 1. The survey results of aboveground plant community also indicated low plant diversity at site 1. The soil seed banks of the other sites had relatively high diversity, possibly due to the high shade effect of the tree-dominated forest.

Effect of soil seed banks on restoration and regeneration of aboveground vegetation

The relationships between soil seed bank and aboveground vegetation were classified into three types by Whipple (1978): first type, both plants and their seeds were found; second type, only seeds were found in soil; third type, only aboveground plants were found. In this study, 21.4%–49% of species recorded as seed in soil seed banks were not found in the aboveground plant community. Totals of 18 herb species and 9 woody plant species were recorded in both the soil seed bank and in the aboveground vegetation. This inconsistency in plant species representation might result from their systems of reproduction, the yield and life span of seeds, the research schedule, and the research methods. Feng et al. (2007) found in disturbed habitats that the species composition of the soil seed bank was similar to that of the aboveground vegetation; however this similarity decreased gradually with the development of the plant community. In changeable environments, this similarity can be 40–60%, even reaching 80%–95% (Henderson 1988). Compared with woody plants, herbs have shorter life spans and higher seed setting rates. In addition, herb seeds readily germinate without evident dormancy. These characteristics lead to the high relative abundance of annual herb seeds in the soil seed bank.

The seeds in the soil bank are derived from the aboveground vegetation. The growth status and reproductive ability of aboveground plants directly influence the species composition and changes in the soil seed bank. As an important seed resource, the soil seed bank participates in the natural regeneration of aboveground vegetation through seed germination and growth. The plant community survey results at all study sites showed that the importance values of afforestation species remained high, at 40-90%. This suggests that there was a close relationship between the soil seed bank and the regeneration of tree species. At the shrub layer, four species, *Z. jujube*, *L. bicolor*, *G. biloba*, and *V. negundo*, were widely distributed in the plots, and all developed through natural regeneration. The plant community was at an early stage of succession, and most of the plants were light-loving plants. These native plant species with high adaptability should be chosen prior to others for vegetation restoration in rocky mountain areas.

In the arid rocky mountain region of north China, aerial seed-

ing method was often used in afforestation projects, and coniferous trees, such as *P. tabulaeformis* and *P. orientalis* were planted. But owing to poor environmental conditions, these trees grew slowly, and did not develop a continuous forest. In the west mountain experimental tree farm of Beijing, the broad-leaved trees with a high resistance to drought and infertile soil were planted, and these plants grew well, forming a forest with high canopy density. This community can improve the site condition significantly and will gradually succeed to a natural plant community. Thus in the arid rocky mountain region, planting tree species typical of early successional stages can not only improve site conditions, but also contribute to the role of the soil seed bank in vegetation restoration. This afforestation pattern is helpful to enrich species representation in plant communities and accelerate the development and formation of natural plant communities. Its ecological outcome was better than that yielded by the afforestation practice of planting the coniferous species that would be typical of late stages of succession. The soil seed bank played a key role in the transformation from artificial pure forest to natural forest, improving the natural ecological succession. In the rocky mountain region with low vegetation coverage rates and poor site conditions, the borrowed soil containing seed bank can be considered for use in vegetation restoration in combination with the transplantation of tree species. Since the plants originating from the soil seed bank exhibit strong adaptability, this method is advantageous to the formation of stable plant communities, shortening the restoration time.

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